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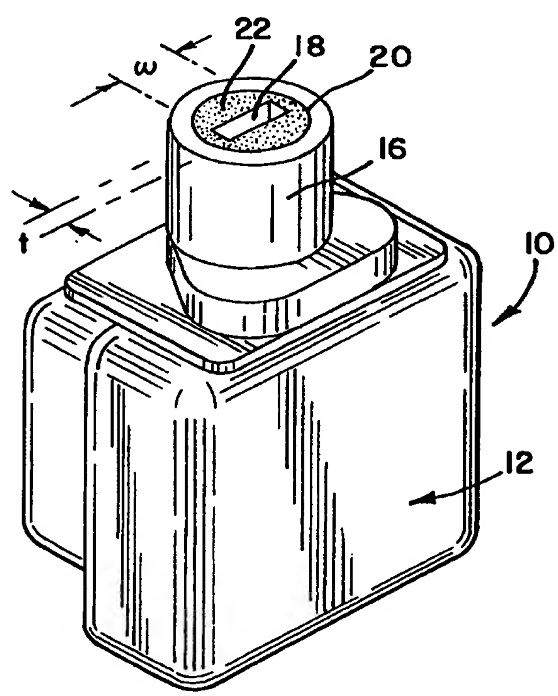
(54) Title: MICROPHONE WITH MODIFIED HIGH–FREQUENCY RESPONSE

(57) Abstract

A microphone having a reduced high frequency response is disclosed. The microphone comprises a housing (12), a diaphragm defining a front cavity and a back cavity, and an inlet port (20) acoustically communicating to the front cavity. The inlet port and front cavity cooperatively form an input sound path. A slot (18) is disposed in the input sound path for increasing the effective inertance and resistance to sound presented to the inlet port. According to one embodiment, the inlet port (20) includes an inlet tube (16), and the slot (18) is disposed within the inlet tube (16). According to another embodiment, the slot (18) is formed in the front cavity.



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MICROPHONE WITH MODIFIED HIGH-FREQUENCY RESPONSE

DESCRIPTION

Technical Field

The present invention relates to a microphone for a hearing aid having a modified high frequency response, such as to eliminate possible high frequency oscillations when coupled to a hearing aid receiver.

Background of the Invention

A hearing aid typically comprises a microphone and a receiver. The microphone receives sound and converts the received sound to an electrical signal. The receiver takes the electrical signal and converts it to sound. An amplifier is typically disposed between the microphone and the receiver.

As a result of various factors, including the inertance of air within the microphone, conventional miniature microphones have a response curve having a peak generally around 5.5 - 7 kHz. In fact, typically the smaller the microphone, the higher the peak frequency. Similarly, conventional receivers also have a response having multiple peaks. When one of these microphones is coupled to one of these receivers, the resulting closed loop gain can result in high frequency oscillations, due to feedback consisting of sound leaking back from the receiver to the microphone. This feedback is quite undesirable, and often results in a significant number of hearing aids being returned.

It is known that by increasing the inertance presented to sound entering the microphone, the frequency of the peak response of the microphone can be reduced to a frequency which will eliminate this feedback. While this would reduce the high frequency performance of the hearing aid, hearing aid manufacturers have

indicated a willingness to accept the reduction as a tradeoff for reduced high frequency oscillations, or feedback.

Holesha, U.S. Patent No. 5,319,717, discloses a method of adding inertance to lower the peak frequency by disposing a C-shaped shim within the input chamber to form an elongated sound path. The elongated sound path increases the effective inertance of the input chamber to thereby lower the frequency of the peak response of the microphone to a frequency lower than the frequency of the peak response of a conventional receiver coupled thereto to eliminate high frequency oscillations. Holesha, however, was found not to be effective because it caused environmental failures due to diaphragm collapse, as a result of the close proximity of the shim to the diaphragm and because the peak damping produced was difficult to control.

In the past, screens have been placed in the inlet tube of microphones to increase the resistance and, hence, dampen the response peak of the microphones. However, these have tended to facilitate clogging of the tubes.

An elongated inlet tube extending from an inlet port has been found to have the effect of increasing the inertance presented to the air as it travels to the diaphragm, thereby lowering the frequency of the peak response of the microphone. The diameter of a generally cylindrical inlet tube may be modified to adjust the peak frequency. Reducing the diameter of the inlet port will decrease the peak frequency. Reducing the diameter of the inlet port will also increase the damping, however, the increase in the damping may not be adequate because the damping and the peak frequency are not independently adjustable. As shown by simplified equations below, where l_t represents the length of the tube, r represents the radius of the tube, η_o represents the viscosity of air, and ρ_o represents the density of air, both the damping

resistance of the port, R_{tube}, and the inertance of the port, L_{tube}, are controlled by the length of the tube and a power of its radius, as follows:

$$R_{tube} = 8 \cdot \eta_o \cdot \frac{l_t}{\pi \cdot r^4}$$

$$L_{tube} = \frac{4}{3} \cdot \rho_o \cdot \frac{l_t}{\pi \cdot r^2}$$

A slot to increase the inertance presented to air entering the microphone can also be formed by lowering the diaphragm to decrease the height of the microphone's front cavity. The cross-sectional area and depth of the front cavity control the inertance and the resistance the front cavity, as described by the simplified equations below.

<u>Summary of the Invention</u>

It is an object of the invention to provide a microphone having a reduced high frequency response without the need for a screen in the inlet tube. In accordance with the invention, the microphone comprises a housing, a diaphragm defining a front cavity and a back cavity, and an inlet port acoustically communicating to the front cavity. The inlet port and front cavity cooperatively form an input sound path. A slot is disposed in the input sound path for increasing the effective inertance to sound presented to the inlet port.

According to one embodiment, it is contemplated that the inlet port includes an inlet tube, and the slot is disposed within the inlet tube.

According to another embodiment, the slot is formed in the front cavity.

Other advantages and aspects of the present invention will become apparent upon reading the following description of the drawings and detailed description of the invention.

Brief Description of the Drawings

FIG. 1 is a perspective view of a microphone in accordance with a first embodiment of the present invention.

FIG. 2 is a side view of the microphone of FIG. 1;

FIG. 3 is a cross-sectional side view of the microphone of FIG. 1; and,

FIG. 4 is a cross-sectional side view of a microphone in accordance with a second embodiment of the invention.

Detailed Description

While this invention is susceptible of embodiment in many different forms, there is shown in the drawings and will herein be described in detail preferred embodiments of the invention with the understanding that the present disclosure is to be considered as an exemplification of the principles of the invention and is not intended to limit the broad aspect of the invention to the embodiments illustrated.

Referring to Figures 1-3, the structure of the microphone assembly 10 of the first embodiment of the present invention comprises a case or housing 12

which, in the embodiment shown, is generally square in shape and has depending walls 14. A diaphragm 15 is disposed within the housing 12, defining a front cavity 'f' and a back cavity 'b' (FIG. 3).

An inlet tube 16 extends outwardly from one of the depending walls 14 for receiving sound. Sound entering the microphone through the inlet tube 16 passes through a slot 18 in a structure 22, before entering the front cavity. The slot 18 is used to modify the inlet tube 16, and is disposed within the inlet tube 16. Optionally, an aluminum shim stock, which is encapsulated in epoxy to form the structure 22, can be placed within the inlet port 20 and the slot 18 formed when the aluminum is etched out. Preferably, the structure could be formed by injection molding.

The microphone assembly 10 has a modified high frequency response wherein the frequency of the peak response of the microphone assembly 10 is reduced to a frequency lower than the frequency of the peak response of a receiver to which the microphone assembly 10 is ultimately connected. With the slot 18, the peak frequency and the damping may be adjusted independently as shown by the equations below where w represents the width of the slot, t represents the thickness of the slot, R_{slot} represents the damping resistance of the slot, and L_{slot} represents the inertance of the port.

$$R_{slot}=12 \cdot \eta_o \frac{l_t}{w \cdot t^3}$$

$$L_{slot} = 6 \cdot \eta_o \cdot \frac{l_t}{5 \cdot w \cdot t}$$

As shown above, both the inertance and resistance are proportional to l_t and inversely proportional to w, but the inertance is inversely proportional to t while the resistance is inversely proportional to t^3. Thus, by changing the thickness while holding the area constant, the damping may be adjusted without changing the peak frequency, or vice versa.

In the first embodiment, the preferred dimensions are as follows.

t = .004 inches;

w = .059 inches; and

l_t = .060 inches.

A second embodiment of the present invention is illustrated in Figure 4. According to the second embodiment, the structure of the microphone assembly 10' comprises a case or housing 12' which, in the embodiment shown, is also generally square in shape and has depending walls 14'. A diaphragm 15' is disposed within the housing 12', defining a front cavity 'f' and a back cavity 'b'.

An inlet tube 16' extends outwardly from one of the depending walls 14' for receiving sound. Sound enters the microphone 10' via the inlet tube 16' and proceeds into the front cavity. The front cavity has a thickness 't', a width 'w' (not shown) and a depth 'd'. According to this embodiment, the diaphragm has been

lowered to reduce the thickness 't', to thereby cause the front cavity to perform acoustically as a slot 18'.

The microphone assembly 10' accordingly also has a modified high frequency response wherein the frequency of the peak response of the microphone assembly 10' is reduced to a frequency lower than the frequency of the peak response of a receiver to which the microphone assembly 10 is ultimately connected. With the slot 18, the peak frequency and the damping may be adjusted independently.

The inertance and resistance are described by the equations for L_{slot} and R_{slot}, described above. In the preferred embodiment, the thickness t of an otherwise conventional Knowles EM-4046 microphone, available from Knowles Electronics, Inc., of Itasca, Illinois, US, the assignee of this patent application, has been reduced from 0.007" to 0.004". Utilizing these dimensions, the following results were obtained.

	Comparison of Modeled Parameters for EM-4046 Modified Equivalent			
	Screen Damped EM-4046		Modified Equivalent	
Description of Parameter	Parameter	% re Total	Parameter	% re Total
Total Inertance (gm/cm^4)	0.132		0.189	
Slot Inertance (gm/cm^4)	0.065	49%	0.122	65%
Port Inertance (gm/cm^4)	0.045	34%	0.045	24%
Motor Inertance (gm/cm^4)	0.022	17%	0.022	12%
Total Resistance (ohms)	2080		2630	
Slot Resistance (ohms)	875	42%	2200	84%

Port Resistance (ohms)	783	38%	0	0%
Motor Resistance (ohms)	430	21%	430	16%
peak frequency (Hz)	5500		4570	
delta peak (dB)	7.1		6.5	

While the specific embodiments have been illustrated and described, numerous modifications come to mind without significantly departing from the spirit of the invention and the scope of protection is only limited by the scope of the accompanying Claims.

CLAIMS

I CLAIM:

1. A microphone having a reduced high frequency response comprising:

a housing;

a diaphragm defining a front cavity and a back cavity;

an inlet port acoustically communicating to said front cavity, said inlet port and front cavity cooperatively forming in input sound path; and,

a slot disposed in said input sound path for increasing the effective inertance and resistance to sound presented to said inlet port.

2. The microphone of claim 1 wherein said inlet port includes an inlet tube, and said slot is disposed within said inlet tube.

3. The microphone of claim 1 wherein said slot is formed in said front cavity.

FIG.1

1/1

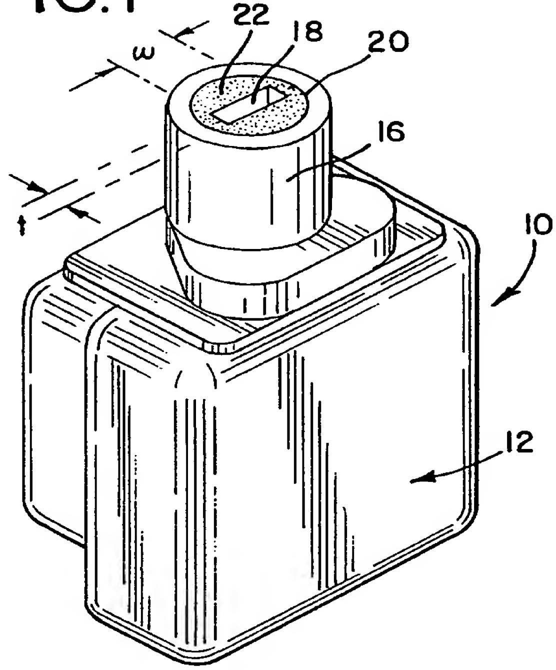


FIG.2

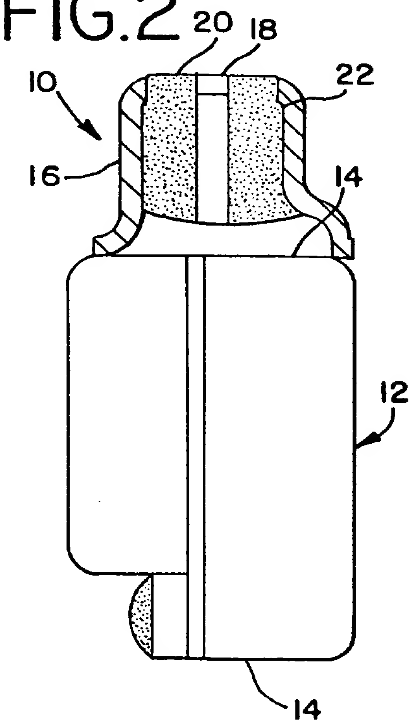


FIG.3

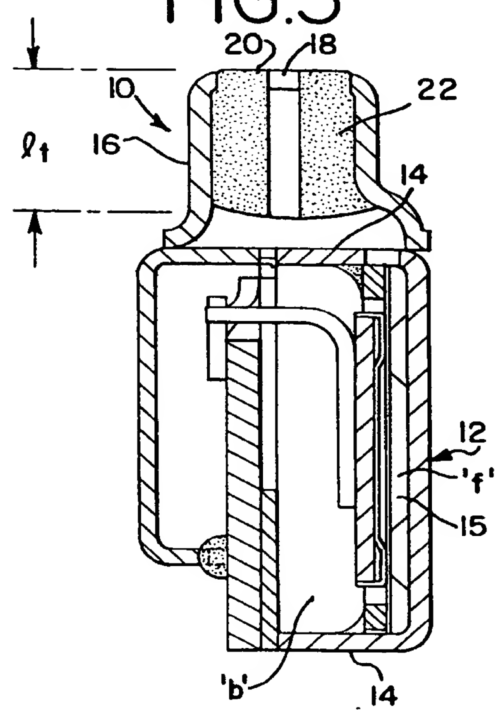
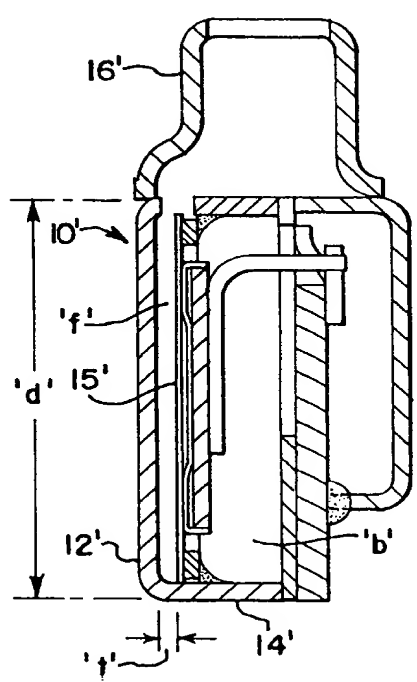


FIG.4



INTERNATIONAL SEARCH REPORT

International application No.
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A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :H04R 25/00
US CL :381/69, 168
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 381/68.6, 69, 153, 154, 158, 159, 168; 181/129, 130, 158, 161.

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

NONE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4,837,833 A (MADAFFARI) 06 June 1989, figure 1.	1-3
A	US 4,815,560 A (MADAFFARI) 28 March 1989, figures 1A and 1B.	1-3
A	US 5,319,717 A (HOLESHA) 07 June 1994, figure 1.	1-3

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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